SUMMARY OF CONFERENCE PROCEEDINGS

INTERNATIONAL CONFERENCE ON RENEWABLE HYDROGEN ECONOMY

"Towards a Secure and Renewable Hydrogen Economy for Asia: Fundamentals, International Experience, and Steps Forward"

National Energy Week 2004
Philippines

Makati Shangri-La Hotel
Makati City, Metro Manila, Philippines
Dec. 7-10, 2004

<u>**Outline**</u>

INTERNATIONAL CONFERENCE
ON
***RENEWABLE* HYDROGEN ECONOMY**
"Towards a Secure and Renewable Hydrogen Economy for Asia: Fundamentals, International Experience, and Steps Forward"

National Energy Week 2004 - Philippines

Makati Shangri-La Hotel
Makati City, Metro Manila, Phillipines
Dec. 7-10, 2004

SUMMARY OF CONFERENCE PROCEEDINGS[1]

1 EXECUTIVE SUMMARY

This report summarizes the results of a conference organized by the USAID Bureau for Asia and the Near East (USAID-ANE) entitled: International Conference on Renewable Hydrogen Economy: *Towards a Secure and Renewable Hydrogen Economy for Asia: Fundamentals, International Experience, and Steps Forward."* The conference was co-hosted by the Philippine Department of Energy on December 7-9 at the Makati Shangri-La Hotel in Makati City, Metro Manila, Philippines in line with the National Energy Week 2004 celebration in the Philippines.

The conference was funded under the South Asia Regional Initiative- Energy (SARI-E) Project of the USAID and was organized principally by the USAID Bureau for Asia and the Near East (USAID-ANE) through its partner entities namely Nexant (India) Ltd., the National Renewable Energy Laboratory (NREL) of the US Department of Energy, the International Institute for Education (IIE). The USAID Mission in the Philippines also provided technical and logistical support.

1.1 Purpose and Structure of the Conference

The purpose of the conference was to bring together renewable hydrogen economy experts and advocates from all over the world with policy-makers, industry, and academia from the North, South and South East Asian nations to identify and outline strategies that can be taken on national, and regional scales towards making the renewable hydrogen economy vision a reality throughout the world.

The itinerary for the conference is attached as Annex A and the list of international and local participants is in Annex B. The conference was organized into the following sessions:

[1] Prepared by Dr. Flordeliza M. Andres, USAID-ANE and Nexant consultant and senior host country coordinator for the conference.

- Day 1, Dec. 7th: RENEWABLE HYDROGEN ECONOMY FUNDAMENTALS

  The purpose of this session was to provide a foundation on the key concepts and building blocks of the renewable hydrogen economy vision from the perspectives of experts and country representatives. Part 2 of this report presents the highlights of the presentations and discussion on the different aspects of technology development and deployment throughout the whole hydrogen energy production and delivery chain.

- Day 2, Dec. 8th: INTERNATIONAL RENEWABLE HYDROGEN EXPERIENCE

  The purpose of this session was for countries actively engaged in promoting renewable hydrogen to share their experience and success stories particularly with those countries that have yet to start on the hydrogen economy pathway. Section 3 of this report compiles the information and insights from the presentations with respect to the renewable hydrogen energy policies and key initiatives and projects of the different countries.

- Day 3, Dec. 9th - THEME: TOWARDS A SECURE AND RENEWABLE HYDROGEN FUTURE FOR ASIA—POSSIBLE PATHWAYS FORWARD

  a) Morning Session: Following Iceland's Hydrogen Economy Lead: Excellent Grade Domestic Renewable Resources, Cheap Electricity, Electrolyzers and Strong Political Will as Ingredients for Joining a Renewable Hydrogen Economy in Asia.

  The purpose of this session was to provide a framework for identifying the ingredients for a renewable hydrogen economy in the North, South and Southeast Asian countries. Section 4.1 of this report puts together the insights and information shared by the speakers on the availability and quality of renewable energy resources, including hydro, geothermal, biomass, solar and wind, and the existing policies and strategies for the development and utilization of such resources.

  (b) Afternoon Session: Stirring the Ingredients for Joining a Renewable Hydrogen Economy: Possible Pathways Forward in Asia

  The purpose of these sessions was to engage conference participants in identifying the strategies and pathways that the North, South and Southeast Asian countries could take on local, national, and regional scales towards making the renewable hydrogen economy vision a reality throughout the world. Representatives from different countries grouped into regional panels outlined possible pathways towards a renewable hydrogen economy drawing from their policies and experience in developing renewable energy resources. Section 4.2 of this report outlines the key points in the presentations.

- Day 4, 10 December 2004: Roundtable on Catalyzing a Secure and Renewable Hydrogen Economy Future for Asia, ADB Headquarters, Manila

- This is a special session hosted by the Asian Development Bank (ADB) for selected participants in the conference. The purpose of the session was to identify opportunities in which the ADB can play a key role in promoting the renewable hydrogen economy vision in Asia.

1.2 Conclusions and Recommendations

The presentations and discussions during the three-day conference validated many of the theories and propositions put forward in the opening sessions and in the reference document prepared for this conference. In particular, there were apparent answers to why, where, how and when to pursue the renewable hydrogen economy, albeit there is more unanimity on the why and where than in the how and when. There is a universal appreciation among the participants, whether from North, South, developed, or developing countries, that a renewable hydrogen economy offers a potential solution to their need for long-term energy security while addressing local and global environmental concerns and thereby promotes global and intergenerational equity. Some countries also expressed appreciation for the externalities that might arise such as the development of a new high-value added industry and the concomitant increase in employment and income generation opportunities.

Much of the technological requirements of a hydrogen economy have already been addressed to support immediate deployment although ongoing research on more advanced technologies and development of codes and standards and appropriate policies can fast track the market development. There is an abundance of renewable energy particularly in Asian developing countries that can be harnessed for hydrogen production. Renewable hydrogen could very well meet the need for distributed generation in isolated communities while hydrogen for transport could complement or displace petrol use in three-wheelers that are part of the mainstream vehicle fleet in developing countries. However costs of conversion technologies particularly electrolyzers and fuel cells still need to come down to make renewable hydrogen energy competitive with fossil-based alternatives. Some participants suggested an easier transition from fossil-based hydrogen generation. A few others suggest that a well-designed hydrogen transition may possibly use less natural gas and coal than business-as-usual and resolve most of the environmental problems of the current fossil-fuel system without creating new ones.

Countries that have hydrogen-related activities already underway see the transition from the technology and market development to full commercialization as happening some 10 to 15 years from now, i.e, by 2015 to 2020. Others are less optimistic and would give it another 5 or even 10 years, i.e., up to 2030 or even 2040. Others are simply “not rushing into it” and would do it at the “right time”. An even more interesting roadmap compares the transition between India and those of Japan and the US with the former trailing behind the latter by 10 to 15 years during the technology and market development periods but thereafter catches up in the commercialization and full realization of the hydrogen economy. This may be a typical attitude of developing (and even some developed) countries that are simply overwhelmed by the costs and institutional requirements of breaking the ground for hydrogen when most renewables have yet to make a significant dent in their energy portfolio, notwithstanding that linking the two together is supposed to deal with most of the issues with renewable energy.

Given the foregoing observations, the following recommendations from the conference (and some from this writer) are worth noting. These recommendations are mostly addressed to international agencies and developed countries.

(a) Continue and intensify RD&D on various aspects of renewable hydrogen economy specifically to address remaining issues such as the following:

- increase efficiencies of electrolyzers;
- reduce cost and increase lifetime of fuel cells;
- eliminate storage problems in transport;
- reduce cost of delivery infrastructure and facilitate mixing or blending of hydrogen with other fuels where appropriate;
- develop appropriate and internationally-harmonized codes and standards that will not unduly pose a barrier to entry of small countries and manufacturers;
- develop, standardize and disseminate methods of comparing the costs and benefits of hydrogen energy and internalizing the environmental and societal benefits.

(b) Encourage and support Asian countries and countries from other regions to join the pursuit of a renewable hydrogen economy to promote large-scale use and bring down the cost of renewable hydrogen energy. This could be done through the following:

- assistance in developing roadmaps or identifying national priorities and pathways for pursuing a renewable hydrogen economy;

- promotion of regional cooperation and strategic collaboration between countries who have had successful hydrogen energy programs to minimize duplication and cost of market development; collaboration should be encouraged at all levels: policy, industry and the academia;

- conduct of worldwide education and outreach campaigns to complement local programs to increase awareness of the benefits and public acceptance of hydrogen economy;

- disseminate business opportunities not only through international conferences and expositions but in more focused groups to capture the attention of policy-makers and investors by placing the hydrogen agenda in international energy meetings such as the APEC Energy Working Group, ASEAN Energy Ministers' Meetings, and the ASEAN Energy Business Forum. This is particularly important during the period of market development to enlist government support in formulating appropriate legislation and regulation to encourage investments and allocating budgets for RD&D; and

- facilitate technology transfer by encouraging public and private investments in renewable hydrogen technologies in countries where such investments might have the largest impact in reducing greenhouse gas emissions, i.e., explore tie-up with clean development mechanism (CDM) and emission trading schemes.

2 Topics and Key Issues Discussed

The conference itinerary indicates the range of topics covered in the conference. The topics can be grouped into: (a) the renewable hydrogen economy vision and objectives; (b) technology development and deployment for each part of the hydrogen energy chain, i.e. state-of-the art, costs, codes and standards, education and outreach programs, and policy levers; (c) international experience; and (d) ingredients and possible pathways for a hydrogen economy in Asia. Following is a brief summary of the presentations and key issues discussed under each of these topics.

2.1 Renewable Hydrogen Economy Vision

The keynote speakers described the vision of a renewable hydrogen economy from various perspectives. A common goal is apparent: to promote the production of hydrogen as an 'energy carrier' from renewable energy resources with the view to provide an inexhaustible supply of energy while addressing global and inter-generational equity with renewables being more geographically distributed and environmentally benign.

- In her opening speech, Dr Cynthia Lowry, Senior Energy Adviser, USAID Bureau for Asia and the Near East, and principal organizer of the conference described the hydrogen economy vision using three key words: *dreams, marriage* and *equality*. Following the lead of Iceland, Dr. Lowry said her *dream* is for the renewable hydrogen economy vision to happen in Asia and to even fast forward for three reasons: (a) Asian energy demand is growing fastest in the world, (b) most Asian countries are net oil importers while oil continues to be scarce; and (c) renewable energy sources such as solar, wind and hydropower are abundant in the region. *Marrying* or linking hydrogen with renewables addresses the intermittency problem or mismatch of supply and demand that makes renewable energy expensive to develop. Excess or off-peak power from renewables can provide cheap electricity to run electrolyzers that would produce hydrogen, which can be stored and converted into energy for different applications. Using renewables to produce hydrogen would also promote equality and equity among nations, since renewables are more geographically distributed compared to fossil energy resources.

- Secretary Vincent Perez of the Philippine Department of Energy said that the hydrogen economy vision fits well into the Philippines' energy independence agenda, which is premised on harnessing the country's vast potential of renewable energy sources, including geothermal wind and biomass, and forging strategic alliances with other countries as the key strategies. The Secretary also mentioned that harnessing hydrogen for energy was identified as a major cooperation program in ASEAN[2] under the ASEAN Plan for Energy Cooperation 2004-2009. The Philippines is currently the chair of the ASEAN Ministers for Energy Meeting (AMEM) and this is one of the principal reasons for choosing the Philippines as the venue of the Conference.

- Undersecretary Abaya of the Philippine Department of Energy said that the voracious appetite for energy in emerging economies is a key to their success. Hydrogen being the most abundant element on earth offers a sustainable, alternative supply of energy for many countries in Asia, especially China and India, which have large population, increasing energy demand and dwindling supply of energy.

- Undersecretary Balce likewise noted that hydrogen is a solution to energy import dependence of countries like the Philippines. Within ASEAN, only three countries are net exporters of energy, thus it is important for ASEAN as a region to pursue the renewable hydrogen economy. The Philippines can spearhead a feasibility study because of its leadership and ASEAN and also because it has an abundant source of renewable energy.

- According to Dr. Jim Ohi of the National Renewable Energy Laboratory (NREL), USA, the concept of the hydrogen economy vision is to facilitate linkages in three areas: *technology*, *environment* and *institutions*. In terms of technology, the hydrogen economy vision enables the linkage between renewable energy systems (i.e., wind, PV, solar thermal, and biomass) and zero-emission energy conversion technologies such as hydrogen storage and fuel cells. On environment, it allows the simultaneous achievement of global development and ecological equity initiatives due to the synergies of renewable hydrogen energy systems with climate change mitigation, sustainable development and biodiversity concepts. Finally, with respect to institutions, the hydrogen economy enables local development consistent with current strategies such as distributed energy generation, development of local or regional resources, and energy deregulation while preserving environmental quality.

- Dr. Jim Ohi also presented the hydrogen economy vision of the International Energy Agency (IEA), which is a hydrogen future based on a clean sustainable energy supply of global proportions that plays a key role in all sectors of the economy. The IEA has been promoting hydrogen for the past 25 years through the Hydrogen Implementing Agreements (HIA), in line with its strategy to facilitate, coordinate and maintain innovative research, development and demonstration activities through international cooperation and information exchange. NREL plays a secretariat role to the IEA.

- According to Mr. Michael Mills, the International Partnership for the Hydrogen Economy (IPHE), which was launched in November 2003, aims to efficiently organize and coordinate multinational research, development and deployment programs that advance the transition to a global hydrogen economy.

[2] Association of South East Asian Nations – its members are Brunei, Cambodia, Indonesia, Malaysia, Myanmar, Laos, Philippines, Singapore, Thailand and Vietnam.

Representatives from various countries cited different objectives for pursuing a renewable hydrogen economy, but common themes are the desire to do away from dependence on imported energy and meet their economic aspirations while addressing environmental concerns. A few other countries mentioned additional goals such as promoting a new, high value-added industry and consequently increase opportunities employment of highly skilled manpower and income generation.

2.2 Technology Development

To pursue the renewable hydrogen economy vision, technology is an important element that must be addressed. Despite many years of research, development and demonstration that have been put into it by international agencies and a few countries, renewable hydrogen energy is still a new concept. Countries wishing to pursue the hydrogen economy are concerned with the state-of-the-art and costs of the various technologies throughout the whole hydrogen energy production and utilization chain and the policy levers needed for their development and commercialization. Following is a summary of the information and insights shared by experts and resource persons from various countries on these issues.

2.2.1 Production

Hydrogen can be produced from a variety of energy sources, both fossil and renewable. The most advanced means of producing hydrogen is through steam reforming using natural gas and coal gasification. These processes, however, needs to be combined with carbon capture and storage (CC & S) to reduce carbon dioxide emissions. Unfortunately, CC & S technologies are still under development, as cited by the International Energy Agency (IEA).

Significant strides have been made towards developing the technologies for producing hydrogen from renewables. The most popular method is electrolysis, which uses electricity to separate hydrogen from oxygen. A number of speakers pointed out that using the electricity produced from renewable energy sources, such as hydro, solar, and wind not only avoids greenhouse gas emissions but also deals with the intermittency problem or mismatch of supply and demand that makes renewable energy generation expensive. According to Mr. Javier Brey, of Hynergreen Technologies and the European Union Framework Program, the combined use of hydrogen, as an electric energy "buffer", with the possibility of distributed production and storage, can even prevent blackouts caused by excessive electricity demand peaks.

The cost of producing hydrogen varies depending on the source, scale, and technology, among other factors. A number of speakers showed the current and potential costs of producing hydrogen from different sources. Dr. Jeff Serfass of the National Hydrogen Association (NHA) of the US showed a comparative cost of hydrogen production from different sources. The cost of production from centralized generating stations using natural gas and coal (with carbon sequestration) is about US$ 2.1 and US$2.25 per kg, respectively. while production from renewables range from US$ 7/kg for wind and biomass to US$ 10/kg for solar. The price differential is expected to narrow down in the future although the exact timing and drivers were not indicated other than the improvement in electrolyzer efficiency from 65% to 80%.

The IEA also cited some figures but they cannot be compared with those of the NHA due to differing units and without sufficient understanding of the underlying assumptions. Nonetheless, IEA's figures showed about the same price differential between hydrogen produced from wind and solar and CO2-free hydrogen from coal and natural gas.

2.2.2 Storage and Delivery

Hydrogen for transportation application can be stored by compressing it and storing in high-pressure metal and composite storage tanks. It can also be stored in liquid form in super-insulated tanks. Storage technologies currently under development include metal hydride tanks, which absorb and release hydrogen with the application of heat, and carbon nanotubes, which are similar to metal hydrides in their mechanism for storing and releasing hydrogen but has the advantage of being able to store significant volumes of hydrogen.

As presented by Dr. Khrisna Sapru of Energy Conversion Devices (ECD, Inc.), ECD has demonstrated a technology for on-board hydrogen storage for vehicles. In a USAID (ANE-PPA) project with Bajaj Automotive Ltd. (BAL), the largest three-wheeler manufacturer in India, ECD has converted a CNG vehicle to run on hydrogen and designed and fabricated the storage system using proprietary solid state, low-pressure, metal hydride technology, for on-board hydrogen storage. Dr. Jim Ohi discussed NREL's research on carbon nanotubes and other advanced storage technologies.

Figures from SIAM in India cited by Mr. Tapan Basu showed cost estimates of hydrogen storage in vehicles with the liquid hydrogen being the cheapest at $2/kwh while complex hydride and compressed gas at 10000 psi are the most expensive at $16/kwh.

2.2.3 Conversion

The most common technologies for conversion are fuel cells and internal combustion engines (ICEs). Fuel cells convert hydrogen to useful energy for various applications while ICEs burn hydrogen directly as fuel for transport and power generation.

2.2.3.1 Fuel Cells

Fuel cells are of different types, depending on the type of electrolyte used. Various speakers talked about the advantages and disadvantages of the most popular types known today, namely Polymer Electrolyte Membrane Fuel Cells (PEMFC), Sulfur Oxide Fuel Cells (SOFC), Direct Methanol Fuel Cell (DMC), and Alkaline Fuel Cells (AFC).

(a) PEMFC

(b) SOFC

Mr. Hiang-Kwee Ho of the Nanyang Technological University, Singapore, gave his insights on SOFC technology based on the results of their research in Singapore: He cited the advantages of SOFC as follows:

- operates at very high temperature: 800 – 1100°C;
- enables internal reforming of fossil and bio-fuels, no need for precious metal catalysts;
- "Conventional" materials
- high quality waste heat – for hybrid cycles and very high efficiencies for cogeneration.

However, he also pointed out some challenges such as the need for better materials, thermal/ mechanical stresses, stability/durability, system dynamics, sealing, manufacturing, balance of plant, and managing complexity.

Mr. Ho also said that the SOFC-based hybrid system is the advanced power plant of the future with potential efficiencies for a fuel cell/gas turbine hybrid system with 10-MW power output of about 70% (LHV) as opposed to 40% for an internal combustion engine and 30% for a simple-cycle gas turbine.

2.2.3.2 Internal Combustion Engines (ICEs)

As presented by Mr. Matthew Abraham, ICEs can use pure or "neat" hydrogen or hydrogen in combination with diesel, gasoline, CNG and LPG. Dual fuelling with diesel and hydrogen is also possible. ICEs can burn hydrogen with minor technical changes and slight efficiency reductions. There are concerns about the use of neat hydrogen such as pre-ignition and backfire and formation of NOx (albeit with near zero emission of CO, HC and CO2) but causes and solutions appear to have been identified. Pre-ignition and backfire is attributed to current hydrogen engine designs having been modified from existing gasoline engines. Mr. Abraham said that there is a need to have dedicated design of combustion chamber & coolant system to accommodate unique needs of hydrogen fuel. On the other hand, the formation of NOx is caused by high stoichiometric air fuel ratio and can be solved by having wide flammability range for effective combustion, water injection, exhaust gas recirculation (EGR) and using liquid hydrogen.

Mr. Abraham argues that safety should not be a concern in hydrogen because it has limited explosive risk, i.e., it is explosive only in high concentrations. It is even safer than gasoline. The negative perception against hydrogen safety must be addressed because it is a barrier for easy acceptability of the fuel.

Dr. L.M. Das of the Center for Energy Studies, Indian Institute of Technology also cited other practical problems confronted in testing ICES such as rapid rate of pressure rise, knocking, low power output, and high NOx emissions at high power output. An ultra lean operation achievable with hydrogen engine drastically reduces NOx.

Dr. Das identified the main areas of hydrogen engine technology as follows:

- Conversion of conventional (and some experimental) gasoline and diesel engines to operate with hydrogen

- Determination of performance characteristics (including emissions), and problems of converted engines
- Development of methods for overcoming the performance problems

2.2.4 End-Use Applications

Hydrogen energy can be used for almost all types of end-uses depending on the conversion device. It can be used to fuel gas turbines for central power station or distributed "on-site" generation and to run internal combustion engines for vehicles, distributed generation and combined heat and power systems (CHP). With fuel cells, hydrogen can be used for distributed generation, transport as well as portable applications. As with hydrogen production, various speakers had different notions of the timing for the full development and commercialization of fuel cells, ranging from 10 to 15 years. Likewise cost estimates vary.

<u>Fuel cells for automotive applications vs. Conventional IC engines</u>

Dr. M. Raja of Tata Motors, India cited the advantages of ICEs over fuel cells: (a) they are easy to produce, (b) well established technology and availability of infra structure for refueling. The issues, however, are limited Carnot efficiency, polluting nature, ECU system are simple and cost effectiveness.

Fuel cell engines, on the other hand, have the advantages of high efficiency (varies from 40-60% for PEMFC) and renewable, sustainable hydrogen fuel. There are many challenges, however, including the high production costs of hydrogen and fuel cell; durability; lack of infrastructure for refueling; complicated electronic controls and ECU system; and on-board storage of hydrogen

From the IEA perspective, Mr. Brett Jacobs' presentation showed that fuel cells cost cost around $3,000-5.000/kW (vs ICEs cost < $ 50/kW) but large-scale production could bring down the cost to $300-350/kW. The lifetime of fuel cells is 30-50% less than ICEs but efficiency is twice that of ICEs. Dr. Jeff Serfass of NHA also notes that fuel cells currently cost about $3,000/kW, whereas transportation requires $50/kW to compete with the gasoline ICE.

Fuel cells for distributed generation might be an easier target than transport. The IEA estimates the current DG market growth at 4%/yr, (albeit oil-gas engines are growing at 65%). About 50 MW of fuel cell capacity is installed and growing at 8 MW/year. Oil-gas engines cost around US$ 500-900 per kW while cost of large fuel cells range from US$4000 – 6000 per kW. Stationary power generation requires $800/kW

In terms of durability, Dr. Serfass notes that vehicles need 5,000 hr lifetime, whereas primary stationary power needs 50,000 hr (emergency power needs only 5,000 hr). The "head of the pack" is only about halfway to both durability targets.

2.2.5 Safety, Standards, Codes and Regulations

As with any new technology, a fundamental challenge to the commercialization of hydrogen energy technologies is the lack of safety information on hydrogen components and systems used in a hydrogen fuel infrastructure. Another challenge is the limited availability of uniform international codes and standards necessary to standardize technology and increase the confidence of local, regional and national officials in the use of hydrogen and fuel cell technology.

Dr. Jim Ohi talked about the USDOE program to formulate standards for the hydrogen industry. The program aims to (a) facilitate the creation and adoption of standards and model building codes for hydrogen systems in commercial, residential, and transportation applications; and (b) harmonize the technical requirements of international standards and regulations. To-date the program has established national templates for H2 vehicle systems and for H2 generator and stationary and portable fuel cells. Following the ANSI process, the national templates will be submitted to a "voluntary consensus process" whereby a working group of experts would translate the templates into standards, which will eventually be adopted into the local, state, federal, and international regulation.

2.2.6 Education and Outreach

Various speakers emphasized the importance of an intensive education and outreach (E & O) program for seeking public acceptance for a new concept or technology such as hydrogen energy. The speakers discussed the content, approach, and results of their E & O programs.

According to Mr. Jon Skulason of Icelandic New Energy, Ltd., public understanding and acceptance of hydrogen being too technical a subject was a great challenge in Iceland. Thus, Iceland made the information material as simple as possible. The success of the hydrogen program is indicated by a 93% public acceptance rating which they got from early and even in the newest surveys. He also noted that regulatory or permitting people were the most difficult to educate. He suggested that IEA and other international agencies focus on them. Another important issue that countries must face is who should spend for education. He also noted that the hydrogen industry is doing a lot of education and has made a lot of material, many of which are accessible from the IPHE website.

Dr. Jeff Serfass of the National Hydrogen Association, USA that an education and Outreach program is needed to address early on the issues of safety and codes and standards and must be addressed to national and local policy-makers, business/investors, teachers and students, and the public at large.

Education and outreach products of NHA include:

- Safety, Codes and Standards Workshops
- Vision Setting
- Roadmap Development
- Conferences
- Fact Sheets
- Speeches
- Videos
- Teacher Curriculum Development

Ms. Chie Watanabe, of the Japan Automobile Research Institute (JARI) cited their outreach activities under the Japan Hydrogen Fuel Cell Demonstration Project (JHFC), which include the demonstration of fuel cell vehicles (FCVs) and hydrogen stations.

Public Relations activities of JHFC include

- JHFC Park Open House on Weekdays
- Hydrogen Station Opening Ceremony
- FCV School for Kids
- FCV School in JHFC Park
- JHFC Hydrogen Station Tour
- the 37th Tokyo Motor Show
- a JHFC Seminar
- participation in various conference & events
- JHFC website and other publicity materials.

A public opinion survey conducted by the JHFC in July 2002 showed that the combined total of those "who knew" and "have heard" about fuel cells was 57% of those surveyed and in July 2003, the number increased to 68%.

2.2.7 Hydrogen Systems Economics: Life Cycle Analyses (LCA) and International National Accounting Systems

Mr. Rupert Merer of Stuart Energy Systems, Canada, discussed the approach and assumptions for conducting a Life Cycle Analyses (LCA) of renewable hydrogen using three case studies: (a) Industrial and Transport Hydrogen Supply - > 1MW (wind and hydro); (b) Remote Power – Diesel; (c) Remote Power – Solar

Industrial and Transportation Supply

- Assumptions for economic analysis
  - Capacity Factor
    - Situation dependant – 50%-90%
    - Relative size of wind turbine to electrolyser
    - Wind profile
  - Electricity transmission capacity and demand
  - Electricity Price - Large hydro, wind with good resource, $.03-.06 /kWhr, declining over time
  - Electrolyser Price
    - MW scale electrolyser at $750 /kW
    - 53 kWhr/kg
    - 10 year lifetime
    - 2.5% O&M cost
    - 12% cost of capital
  - Electrolyser efficiency
  - Lifetime
  - Cost of Capital

- O&M
- Other infrastructure cost - for highly utilized fuelling station – approximately same as electrolyser
- Other Revenue Streams
  - Electricity on demand (grid market – w/ storage)
    - Responsive reserve market at $7-10 /MWhr
    - Open market arbitrage
  - oxygen by-product @ $25 per tonne
    - 8 kg oxygen/kg hydrogen
    - $25/tonne yields $.20/kg (approx $4 /MWh credit for electricity)
  - D20 $4-$5 / MWh of input power (same as O2)

2.2.7 Policy Levers

Government Roles in the US

Dr. Jeff Serfass of the National Hydrogen Association, USA, talked about government roles and policies in promoting renewables in the US.

- Leadership in setting public policy
  - Advocacy
  - International cooperation
- Fund basic research and validation demonstrations
- Facilitate Codes & Standards development
- Support public education
- Investment and use incentives

US Policies on Renewables

- National Renewable Portfolio Standard Being Considered
  - Unlikely to Affect Hydrogen in Near Term
- States are Leading RPS Adoption
  - Unlikely to Affect Hydrogen in Near Term
- Drivers for Renewable Hydrogen
  - State, Regional and Local Health and Air Quality
  - Use of Domestic Resources in States
    - Reducing Outward Cash Flow
    - Economic Development
- Asian Country Interests Create Stronger Driver for Renewables
  - Renewable Hydrogen Leadership Opportunity

Renewable Energy Policy for Developing Countries

Dr. David Renne of NREL, USA talked about the Renewable Energy Policy Compendium that he prepared for Sri Lanka under the USAID/SARI-Energy project. (A copy of the compendium was distributed to the participants in this conference.)

The Compendium Objectives

- Assist Government of Sri Lanka to consider policies that advance use of RE technologies
- Examine examples and lessons learned from around the world
- Provide specific policy incentives and legislative examples
- Provide case studies

Selected RE Policies

- Price-based policies
- Electric feed-in laws
- Tax incentives (investment, production)
- Other (real-time pricing, net metering, green pricing, standardized interconnection rules)
- Quota-Based approaches
- RE Portfolio Standards
- Non-Fossil Fuel Obligation and Concession Bidding

Summary

- Many tools for policy are available
- For smaller, developing countries (Sri Lanka), evaluation of policy may be easier, but options may be limited
- National objectives for RE deployment must be consistent with institutional objectives
- Most significant factor will be costs associated with financing policy measures
- Maximizing flexibility of policies to promote RE is critical

Representatives of other countries also discussed policies on renewables and/or hydrogen. These are included in the next sections.

3 International Experience

This section puts together the highlights of the presentations on the individual experience of the countries represented in the conference. The presentations indicate a dynamic policy and strong institutions for renewable and/or hydrogen energy promotion and in some cases active participation from the industry and private sector. Some countries have set their long-term vision or roadmaps with timetables and strategies for pursuing a hydrogen economy. Developed countries such as Iceland, the USA, Japan that are way ahead in the development and adoption of hydrogen and fuel cell technologies have rather active education and outreach programs. However, there is also a significant activity in the research, development and demonstration of hydrogen and fuel cell technologies in Asian countries, particularly in India, Malaysia and Singapore.

3.1 European Panel: Iceland, Netherlands, and the European Union

3.1.1 Iceland

Accomplishments

To-date, Iceland's hydrogen program has accomplished the following:

- Most km driven in 2004 (CUTE/ECTOS) – 45,000 km to date (2003-2004)
- Highest availability in 2004 (CUTE/ECTOS)
- Pumped over 7,000 kg of hydrogen
- Saved over 20,000 litres of diesel and more than 50 tons less greenhouse gas emissions
- Indication that over 90% of the public is positive toward the new fuel

Success Factors

Mr. Skulason attributes the success of the hydrogen program in Iceland to the following:

- Iceland has the unique circumstances to enable operating a "hydrogen based fuel project" in a CO2 neutral environment
- Iceland has similar standards and transportation system as most other developed countries and therefore the results can easily be adapted elsewhere
- Iceland has experience in converting from one energy source to another
- It is very important that the project makes a big impact (real-scale project)
- The new technology needs to be evaluated under severe weather conditions
- The government of Iceland has announced that it is aiming to transform Iceland into a hydrogen society in the near future

Hydrogen time frame

As presented by Mr. Jon Skulason, Iceland is looking at the following timeframe for its current and future initiatives:

2000- 2010:	Demonstration
Mid 2000 to 2010:	Serial production, transport, including maritime applications;
2010 – 2020:	Mass production/commercialization

Key Initiatives and Projects

- ECTOS – FC bus and infrastructure demonstration
  - Infrastructure projects
    - Integrating hydrogen infrastructure into the existing urban setting in Reykjavik
    - Production; On site electrolyser (using renewable electricity to split water into hydrogen and oxygen). Only supply: WATER and ELECTRICITY
    - Storing; Compressor delivering hydrogen at 440 bar

  - Distribution on site of gaseous hydrogen directly on to vehicles.

- ECTOS-hydrogen station,
  - An example of pre-commercial filling station; Opened April 24, 2003
  - Only station in the world operating at a conventional gasoline station (has full commercial license)

- EURO-HYPORT – education, infrastructure and export of H2
- Storage of H2
- Geothermal hydrogen
- Hydrogen passenger vehicles (ICEH2 &/or FC)
- Market assessment of small fuel cells
- Social acceptance – Economics (cost benefit, etc) – External costs (NEEDS)
- Marine interest (NEW-H-SHIP)
- Consultancy
- Education

3.1.2 Netherlands

<u>Hydrogen/Energy Policy</u>

As presented by Dr. J.A. Zeevalink of the Environment Energy and Process Innovation TNO-MEP, the Netherlands Energy Policy consist of two sets of priorities:

1. Agreements prepared with industry and other stakeholders to reduce consumption
2. Introduction of renewable energy – target is 5 % of energy consumption in 2010 and 10 % in 2020 – this includes power and heat

Netherlands must also follow the EC directive for renewable fuels, the implementation of which is expected to start end of 2005. Under the Directive: renewables must account for 2 % of energy consumption of the member countries in 2005 and 5.75 % in 2010

<u>Key Hydrogen Initiatives/Projects</u>

Dr. Zeevalink also presented the key H2 initiatives and projects in Netherlands, as follows:

- Research on Supercritical Water Gasification for hydrogen production
- Participation of the City of Amsterdam in the EU funded CUTE project - busses for public transport on hydrogen and hydrogen fueling station
- Feasibility study on power station by Akzo Nobel and NedStack - 200 MW peak; next to chlorine electrolysis plant
- Introduction of hydrogen in the natural gas grid – an EU funded project coordinated by Dutch gas Company
- Multi housing fuel cell projects: also an EU funded demonstration project

3.1.3 European Union

Hydrogen Energy Policy/Strategy

As discussed by Mr. Javier Brey of Abengoa-Hynergreen Technolgies and the European Union Hydrogen Framework Program, the elements of the European Strategy for Hydrogen and Fuel Cells are embodied in the following:

- High Level Group H2 and FCs (HLG) (2002-2003) - Vision report : "*Hydrogen energy and Fuel Cells – A vision of our future*"
- European Hydrogen and Fuel Cell Technology Platform
- Building an ERA in hydrogen
- Projects in Framework Programme 2002-2006 (FP6) - (S-M, M-L)
- FP7 (2006-2010) – new directions and initiatives

Key H2 Initiatives/Projects

- Hydrogen & Fuel Cell Projects

The European Union is implementing a wide array of hydrogen and fuel cell projects under its Framework Programme 2002-2006 (FP6). After the 1st call for proposals, FP6 contracts awarded amounted to 103.3 MM Euro, of which 70.4 MM Euro is for hydrogen, 32.9 MM Euro is for fuel cells. The specific projects are as follows:

1. Hydrogen
    - H2 production
        - Hydrogen rich gas from biomass
        - Solar MSR for synthesis gas Production
        - High Temperature
        - Thermochemical cycles
        - Solid oxide water
        - Electrolyser
        - Photobiological hydrogen production
    - H2 storage - Next generation storage technologies for on-board applications
    - H2 safety, regulations, codes & standards
        - Networking research in safety issues
        - Harmonisation of Standards and regulations
    - H2 pathways
        - Elaborating a European Hydrogen Roadmap
        - European H2/FC Technology Platform Secretariat
        - Investigating infrastructure requirements for H2 and natural gas mixes
        - Innovative high temperature production routes for H2 production
        - Coordination Action to establish a H2 and FC ERA-NET
        - World energy Technology Outlook 2005
        - New models to simulate transition to a H2 economy

    - H2 end use
        - H2 FC fleet demonstration
        - Internal combustion engines

- Effectiveness of demonstration initiatives

2. Fuel Cells
   - High Temperature Fuel Cells
     - Next generations SOFC planar technology
     - Biomass Fuel Cell Utility System
     - SOFC fuelled by biomass gasification gas
     - Porous materials for SOFC / High power applications

   - Portable applications
     - Compact direct (m)ethanol fuel cell
     - Integration of small FC (up to 1 kW) with battery and supercapacitors for non-automotive devices

   - Solid Polymer Fuel Cells
     - Support action to define the technical obstacles to introduce fuel cell in ships
     - Innovative systems and components for road transport applications
     - High temperature polymer electrolyte membrane (PEM)
     - Novel software-based tools for PEM FC components and stacks
     - Intelligent DC/DC converter & FC hybrid power trains
     - Integrate PEMFC, ultracapacitors, MH storage for emergency power supply system

<u>Open Calls for H2 & FCs projects</u>

The European Union currently has Open Calls for H2 & FCs projects as follows:

- Hydrogen storage; H2 production; pre-normative RTD;
- Fuel Cell materials and production; Small and large FC systems integration;
- Socio-economic research
- European Partnership: "Hydrogen for transport" and new hydrogen integrated demonstration projects ("seed" projects for large-scale demonstration) on transport and polygeneration.
- Fuel Cell and Hybrid Vehicle Development; Generic fuel processor tech; Integrated Fuel Cell systems and fuel processors for aeronautics, waterborne and other transport applications
- Support of the co-ordination, assessment and monitoring of research to contribute to the definition phase for a hydrogen communities initiative
- Materials development and processes for fuel cells and hydrogen storage technologies

<u>Renewable Energy Systems & Hydrogen</u>

- H2 production from RES
  - Absorption Enhanced Reforming for clean Biomass Gasification to Hydrogen

- Hydrogen-Rich Fuel Gas From Supercritical Water Gasification of Wine Grape Residues and Greenhouse Rest Biomass
- Production of hydrogen and electricity using Pyrolysis oil from biomass
- FC bus fleet trial in Iceland (ECTOS)
- Hydrogen production and storage from wind energy
- Hydrogen production using Photo voltaic (PV) cells
- Hydrogen production via water splitting using concentrated solar power
- Clean Hydrogen production from Bioethanol
- Biomass and waste conversion in supercritical water for production of renewable Hydrogen

<u>International Cooperation</u>

- Bilateral co-operation agreements with U.S., Japan, Canada, Russia, China, Australia, Brazil and participation in IEA activities
- Participation in the International Partnership for the Hydrogen Economy (IPHE). Concrete projects and initiatives expected in 2005

3.2 North America Panel: Canada and USA

3.2.1 USA

As presented by Dr. Jeff Serfass of the National Hydrogen Association, following are the indicators of the extent of hydrogen deployment in the USA, further plans and key initiatives.

<u>US Fueling Infrastructure</u>

- Public fueling stations are coming
  - About 15 demonstration fueling facilities
  - 170 new stations planned (CA, NV, DC FL) - 1 public station in DC
  - Auto need for hydrogen is developing
  - Less than 100 test vehicles on the road
- Small mobile fueling stations are on the market today -
  - Needs will continue to be met as market grows
- Energy companies getting engaged

<u>Government Roles</u>

- Leadership in setting public policy
  - Advocacy
  - International cooperation
- Fund basic research and validation demonstrations
- Facilitate Codes & Standards development
- Support public education
- Investment and use incentives

DOE Hydrogen Procurements

- Hydrogen Generation from Electrolysis
- Hydrogen Research and Development
- Renewable Energy Development on Tribal Lands
- Hydrogen Production and Delivery Research
- Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project
- Grand Challenge" For Basic and Applied Research In Hydrogen Storage
- Research, Development and Demonstration of Micro CHP Systems for Residential Applications
- Hydrogen Education Development
- Hydrogen Safety, Codes and Standards Research

States/Provinces Leading Local Initiatives

Approximately 20 states are actively developing roadmaps, policies and safety issues with the following states/provinces leading local initiatives.

- California
- Michigan
- New York
- Florida
- British Columbia
- Ontario

California Initiatives

- Hydrogen Highway Initiative
- California Hydrogen Business Council
- California Fuel Cell Partnership
- Clean Cities Hydrogen Refueling Station
- CALSTART Bus Project

Timeline

The transition to a hydrogen future is beginning. The indicators are:

- 8 major automobile companies doing hydrogen vehicle development with nearly 100 vehicles on the road
- 3 major oil companies developing hydrogen business strategies with about 80 fueling station built
- Multiple companies committed to PEM fuel cell development for vehicles
- Portable fuel cells already beginning to emerge for "appliances"
- Commercial fuel cells on the market now for remote power, power back-up, and utility-scale applications
- Early fuel cell fleets by 2010, hydrogen ICE fleets beginning in 2005
- Commercial fleet products around 2015

- Personal vehicles beginning in 2020
- DOE says decision points are in 2015; we think the key decision points are closer to 2010

3.3 North Asia Panel: Japan and Korea

3.3.1 Japan

Mr. Masakazu Takahashi of the Hydrogen and Fuel Cell Promotion Office, Agency for Natural Resources Energy, Ministry of Economy, Trade and Industry (METI), in Japan discussed Japan's energy policy and the relevance of fuel cell.

Japan's Energy Policy: 3Es

- Security of Energy Supply/Alternatives to oil
- Economic Efficiency/Market mechanism
- Harmony with Environment-cutting CO2 emission

Significance of Introducing Fuel Cells

- Highly Efficient - Energy Conservation Effect
- Diversification of Energy Supply
- Creation of New Industry and Jobs/Enhancement of Industrial Competitiveness
- Distributed Energy Resources
- Reducing Impact on Environment

Roadmap

Mr. Takahashi presented the following scenario for practical application and diffusion of fuel cell vehicle and stationary fuel cell in Japan:

- *Firm/industry activities:*
  2002 Ground work and technology demonstration stage: Initial introduction of fuel cell vehicle and stationary fuel cells
  2005 - Introductory stage - Accelerate the introduction of practical fuel cells
  2010 - Diffusion stage- The market will naturally grow and expand
  2010 50,000 Fuel Cell Vehicles; 2.1GW Stationary Fuel Cell
  2020 5,000,000 Fuel Cell Vehicles; Stationary Fuel Cell

- *Policy for accelerating Introduction*
  2002 – 2005: Verification Test: Demonstration programs on FCV for buses, hydrogen station, and stationary fuel cells; reviewing regulations, establishment of standards and harmonization with international standards

- *R & D*
  2002 – 2005: R&D on fuel cells; R&D on using hydrogen
  2005 – 2020: R&D on basic factors for improving performance and cost reduction

METI's Budget for Fuel Cells (Billions of Japanese Yen)

FY 2001: 11.7
FY 2002: 22.0
FY 2003: 30.7
FY 2004: 32.9

Key Initiatives/Projects

- *Fuel Cell Demonstration Project*

As noted in the above scenario, Japan is implementing a Fuel Cell Demonstration Project with the view to get data and information about (a) R&D barriers; (b) Emission; (c) Energy efficiency (well to wheel); (d) Fuel quality standard; (e) Safety.

It also aims to establish public acceptance about fuel cell and hydrogen, through implementation of demonstration test under real conditions. The project involves demonstration of (a) fuel cell buses using PEFC and 10 hydrogen supply stations with different fuel sources and (b) fuel cells for Electric Power supply for the National Pavilion using PAFC (800kW), MCFC (720kW) and SOFC (50kW).

3.3.2 Korea

Hydrogen/Alternative Energy Policy

As presented by Dr. Heesung Shin of the Korea Institute of Energy Research, the Korean government provides supports for alternative energy by means of the following:

- Subsidy
- A low-interest loan for fuel manufacturers and users – 3.5% for 15 yrs
- Tax Reform: Tariff : 8.0% → 2.8% for all alternative energy equipments; Tax : reduce income tax or corporate tax
- Other: Mandatory installation in public building; Feed-in-tariff under considering

Creation of a National RD&D Organization for Hydrogen and Fuel Cell

Korea's commitment to hydrogen energy is indicated by the creation of a National RD&D Organization for Hydrogen and provision of fiscal incentives for fuel cell RD&D as part of government support for alternative energy. The organization was established in 2003 for the following purposes:

- To expedite the commercialization of hydrogen and fuel cell technology
- Suggest hydrogen economy vision
- Develop a national plan and road map to create a new energy industry
- Set up a detailed action plan to meet nation's dissemination target
- Co-ordinate and allocate RD&D programs supported by government

Key Initiatives/Projects

Dr. Heesung Shin also discussed the status of R&D on H2 and FCs in Korea. The specific R&D projects are as follows:

- Hydrogen
  - Hydrogen Energy R&D Program (Production/Storage/Usage)
  - Hydrogen Production from Nuclear Energy
  - Development and Demonstration of Hydrogen Station

- Fuel Cells
  - Development of 100kW class MCFC System for Application
  - Development of 80kW class PEMFC System for Transportation
  - 3kW PEMFC System for Residential Power Generation
  - 3kw SOFC system for APU Application

3.4 South Asia Panel: India and Pakistan

3.4.1 India

Hydrogen Energy Policy/Strategy

As discussed by Mr. Sanjeev Singh, Director of the Research Department, Indian Oil Corporation Ltd., (IOC-R&D), the Planning Commission (Power & Energy Division) set up a committee in July' 2003 to address various aspects and develop guidelines for Hydrogen Energy in the country.

Four sub-groups were set up to look into the different aspects of hydrogen, namely:

- Hydrogen production
- Hydrogen applications
- Safety standards, security and related policy issues
- Hydrogen storage & distribution

The IOC- R&D was identified as the nodal agency for these activities.

Hydrogen Economy Timeline

Mr. Tapan Basu presented an interesting timeline for the Hydrogen Economy in India, which is benchmarked against the USA and Japan, as follows:

- *Phase I – R, D & D/ Technology Development Phase*

USA	:	2000 – 2030 (30 years)
Japan	:	2000 – 2020 (20 years)
India	:	~ present to 2035 (40 years)

- *Phase II - Transition to Marketplace/ Initial Market Penetration Phase*

USA	:	2010 – 2025	(15 years)
Japan	:	2010 – 2030	(20 years)
India	:	~ present to 2035	(35 years)

- *Phase III - Expansion of Markets and Infrastructure/Infrastructure Investment Phase*

USA	:	~ 2014 – 2035	(15 years)
Japan	:	~ 2015 – 2036	(20 years)
India	:	2014 to 2030	(35 years)

- *Phase IV – Realization of Hydrogen Economy/Fully Developed Market and Infrastructure Phase*

USA	:	2025 – > 2040	(>15 years)
Japan	:	2025 – > 2040	(>15 years)
India	:	2025 - > 2040	(>15 years)

It is interesting how India is envisaged to catch up with the US and Japan in the realization of the hydrogen economy while "lagging" behind or perhaps, relying on these countries to lead the technology and market development. The period for the transition to the hydrogen economy is also longer (2040) than what is envisaged by the Japanese for themselves.

Time line for Hydrogen based Transportation

Dr. M. Raja of the Engineering Research Center, Tata Motors, India also presented a proposed time line for Hydrogen based Transportation which is currently under review by National Hydrogen Board:

Near term (2006)

- *10% hythane IC Engine*
- *30% hythane IC Engine*

Mid term (2008)

Pure Hydrogen IC Engines

Long term vision (2015)

Fuel cell- Electric

Key Initiatives/Projects

a) Oil & Gas Sector - Hydrogen Research Activities

Mr. Sanjeev Singh also presented the hydrogen research activities initiated by the oil and gas sector in India.

- **Proposed Research Plan in Oil & Gas Sector**

  H2 Production

  - Procurement of on-site reforming units for production of hydrogen from natural gas - To be located at two places in Delhi (April 2006)
  - Development of reformer for production of hydrogen from Methanol, Ethanol, Diesel etc
  - Production of hydrogen from steam gasification of biomass and fermentation of biomass
  - Productions of hydrogen from renewable energy sources like solar & wind energy

  Hydrogen Storage

  - Hydrogen storage systems in gaseous form
  - Developmental work for lightweight, cost effective and efficient metal hydride systems
  - Tube trailer / Mobile Fueler
  - Safety codes & practices

  Hydrogen Application

  - Conversion of CNG 3-wheelers and buses to operate on CNG/H2 mixture
  - Development of neat hydrogen powered 3 wheeler and bus engine and vehicle proto types- to be followed by demonstration fleet of 1000 vehicles by 2008
  - Development of hydrogen conversion kit for portable gensets

- **Actions Taken by IOC-R&D**

  - A genset emission test bench established at IOC-R&D to be used for conversion of portable gensets to Hydrogen
  - CNG / H2 mixing & dispensing system –procurement is in final stage.
  - MoC signed with MINDA Industries Ltd for Development of Hydrogen and H2 / CNG mixed Fuelling System for IC Engines on 27th July, 2004.
    - Work on development of CNG / H2 operated genset already started.

- MoC signed with MAHINDRA & MAHINDRA for Development of Hydrogen run 3 – Wheelers and Buses on 25th August, 2004

- **Joint Program of IOC R&D with Govt. Of India for H2 demonstration**

  - Setting up of Hydrogen Production & Fuelling Station.
  - Demonstration Project on blending of 10% Hydrogen with CNG in first phase.
  - R&D work to increase Hydrogen Blending up to 30% with CNG.
  - Study of Hydrogen Delivery options.
  - Creation of Public Awareness about Hydrogen.

- **Other Programmes for Hydrogen Research in India**

  - 1000 H2 vehicles by 2008: 200 buses; 500 small 3-wheelers; 300 big 3-wheelers
  - Auto Industry to spend ~ Rs 55 Crore
    - Development of H2 engine / vehicle
    - Demonstration fleet of 1000 vehicle

3.4.2 Pakistan

On behalf of the Pakistan delegation, Dr. Muhammad Pervez of the Hydrocarbon Development Institute of Pakistan (HDIP) discussed the situation and prospects for renewable hydrogen in Pakistan. .

Situation and Prospects for Renewable Hydrogen

- At present no elaborate policies to support development of renewable hydrogen but there is will both at political and technical levels.
- Some research is in progress on fuel cells and PVs.
- Pakistan has well developed natural gas infrastructure, which can be used for hydrogen.
- Pakistan is widely using natural gas in transport sector. This could be a good transition from natural gas to hydrogen mix and pure fuels in the long-term.
- Photovoltaic installed 650 KW (5-56KW) and 60KW in pipeline.
- Some research is also in progress on fuel cells and PVs both in public and private sector.
- Alternative Energy Development Board has been established in Prime Minister's Secretariat.

Dr. Pervez also presented the proposed action plan for renewable hydrogen and this is discussed in this report in Sec. 4.1.5.4

3.5 South Pacific Panel: Australia and New Zealand

3.5.1 Australia

According to Dr. David Rand of Hydrogen Futures, CSIRO Energy Technology, Australia, the main driver for hydrogen in Australia is the reduction of the intensity of greenhouse gas emissions. However, this may be overtaken by transport fuel security. The hydrogen agenda is likely to be controlled initially by the development of low-emission fossil fuels but the prospects for hydrogen production using renewable energy are high, and the economics could become more favourable.

To date, most action has been on how to produce sustainably large amounts of clean hydrogen, but great challenges remain in distribution, storage and end-use. He also noted that the path to hydrogen penetration into stationary, and particularly transportation, applications requires better definition. Dr. Rand also presented the main mission of government and budget for renewables and hydrogen economy.

Flagship Mission

- To halve greenhouse gas emissions by 2050 (i.e., to 50% of 2002 levels)
- To double the efficiency of the nation's new energy generation, supply and end-use
- To position Australia for a future hydrogen economy

Budget

- 2003 – 04: A$ 26 million → 2008 – 09: A$ 70 million
- A$ 7.2 million for collaboration with universities

R&D Activities: CO2 storage options

- Use of CO2 in enhanced coal-bed methane recovery
- Deep unmineable coal seam
- Depleted oil and gas reservoirs
- Large voids and cavities
- Use of CO2 in enhanced oil recovery
- Deep unused saline, water-saturated, reservoir rocks
- Basalts
- Reaction with brine
- Formation of stable carbonate minerals

3.5.2 New Zealand

3.6 Southeast Asia: Indonesia, Malaysia, Philippines, Singapore, and Thailand \

3.6.1 Indonesia

Hydrogen Energy Pathways

According to Mr. Jan Sopaheluwakan of the Indonesian Institute of Science, there are three hydrogen energy pathways available for regional development in Indonesia

- the "wastes-based" path for cities and inland areas
- the "seawater-based" path for coastal plains and small islands
- combined water-seawater path for coastal cities

3.6.2 Malaysia

Hydrogen Energy Policy

As presented by Prof. Wan Ramli Wan Daud, Head of the National Fuel Cell Research Program Malaysia, international and national policies provide the basis for fuel cell development in Malaysia:

- Kyoto protocol for green house gas reduction ratified as International Law
    - fossil fuels reduction
    - renewable energy increase

- Renewable energy as 5th "fuel" added to coal, oil, gas & hydro in 5 fuel policy
    - Target: 5% renewable energy by 2010

Key Initiatives/Activities

Professor Dr. Hamdani Saidi, of the Universiti Teknologi Malaysia gave an overview of the hydrogen industry in Malaysia and of the R&D activities.

'Hydrogen Industry' In Malaysia

- Generation technology
    - Steam reforming in refineries and petrochemical plants
    - Electrolysis
    - Biomass gasification
    - Pyrolysis process
    - solar
- Current Utilization of hydrogen
    - Food Industry – hydrogenation process in Palm oil industry
    - Feedstock in refinery and petrochemical plant
    - Glass manufacturing industry

New Government Initiatives

- Promotes renewable development concept
    - Fuel diversification program for power generation

- Develops 5th Fuel Policy
  - 5% generation from renewable fuel by 2010
- Develops a road map for hydrogen, fuel cell and solar
- Promotes awareness to public and education
- Promotes R&D in Fuel Cell, solar and renewable energy

<u>Overview of R&D Activities</u>

- Development of Proton Exchange Membranes Fuel Cell (PEMFC) for stationary and mobile power generation
  - Stacks and components
  - Membranes
  - Hydrogen storage
  - Reforming of natural gas and methanol
  - Air-conditioning for buses
  - Fuel Cell powered motorcycle
- R&D in solar and wind
  - Solar PV and heating
  - Day-lighting
  - Electricity generation from wind
- Universities and Research Institutions
  - Universiti Kebangsaan Malaysia (UKM)
  - Universiti Teknologi Malaysia (UTM)
  - Others

<u>National Fuel Cell Program</u>

As presented by Prof. Wan Ramli Wan Daud, Malaysia is implementing a National Fuel Cell Program, which aims to:

- Design, simulate, fabricate and test for the long term performance of a PEM fuel cell system
- Develop and test for long term performance of fuel cell components and
- Develop fuel cell system demonstrations.

Choice of PEMFC

Among the different fuel cell types, Malaysia opts for the PEMFC because of the following reasons:

- It is the least commercialised
- Indigenous polymer electrolyte membrane technology
- Indigenous electrode technology
- Indigenous fuel processing catalyst technology
- Indigenous PEMFC prototyping capability

Products

The products of the Malaysian fuel cell program are:

- Fuel cell powered motorcycle
- Fuel cell powered automotive thermal comfort system
- Microreactor for development of autothermal steam reforming of natural gas catalysts
- Carbon nanotubes for hydrogen storage
- Single cell, open cathode multi-cell & water cooled multi-cell prototypes
- A prototype membrane reactor to produce pure hydrogen
- A prototype compact pressure swing adsorption system for removing CO
- compression molded polymer composite
- A microreactor and catalysts for autothermal steam reforming of methanol into hydrogen
- UKM's solar hydrogen eco-house

The results of Malaysia's research are widely published in International Journals and presented in International Conferences.

3.6.3 Philippines

Hydrogen Energy Policy/Strategy

During his keynote speech and presentation, Secretary Vincent S. Perez of the Philippine Department of Energy said that renewable hydrogen is one of the areas to consider towards achieving the Philippine goal of energy independence. He also cited the challenges and way forward in harnessing hydrogen for energy:

- Information education campaigns are imperative to increase awareness and acceptance of emerging hydrogen economy
- Commercialization of hydrogen for energy would depend on technical and economic considerations
- Technical collaborations between and among countries are necessary for technology transfer
- Technology transfer necessary from countries that have already developed hydrogen as an energy source
- The role of private sector is critical in the success of this initiative

Key Initiatives/Activities

Secretary Perez also cited their current initiatives and plans to harness hydrogen for energy:

- Identified harnessing hydrogen for energy as a major cooperation program in ASEAN during the 22nd AMEM in June 2004 under the ASEAN Plan for Energy Cooperation 2004-2009

- To pursue an ASEAN Hydrogen Program through partnership among the ASEAN Center for Energy, ASEAN Secretariat & USAID with the International Partnership in Hydrogen Economy
- Co-hosting this International Conference on Renewable Hydrogen Economy in Manila, held 7-9 December 2004

Fuel Cell Research Project

As presented by Dr. Leon M. Payawan Jr. of the Philippine National Oil Company (PNOC) and the University of the Philippines, PNOC is undertaking a project entitled "Research on the Use of Conductive Polymer as PEMFC Electrodes and *In Situ* Hydrogen Gas Photogenerator." The aims of the project are:

- To produce a polyelectrolyte membrane (PEM) fuel cell prototype;
- To fabricate a new generation of PEM fuel cells using alternative fuel cell components;
- To develop new sources of hydrogen fuel generation from biological or photochemical reactions.

The proposed fuel cell developed in the study is an electrochemically or chemically synthesized conductive polymer on textile which is amenable to [Pt(Cl)4]2 doping and could lead to a reduced and more efficient Pt catalyst loading.

3.6.4 Singapore

Hydrogen Energy Policy

As presented by Mr. Hiang-Kwee Ho of the Nanyang Technological University, Singapore, Singapore's interest in clean energy and energy efficiency is signified by the following:

- Increased use of natural gas in liberalised energy market *including power generation, transportation, industrial and domestic* fuel - natural gas now accounts for more than 60% of power generation
- Government funding/initiatives
  - SINERGY and Innovation for Environmental Sustainability Fund
  - push to be hub for clean energy and environmental technologies

Key Initiatives/Activities

There is significant activity going on in Singapore on H2 and FC-related RD&D, as also presented by Mr. Hiang Kwee-Ho:

(a) Test Bedding, Demonstration and Development Projects

- *Daimler-Chrysler fuel cell cars*
- *BP (+ Air Products) refueling stations*
- *HDB fuel cell system testing (first system from Idatech/ DRPL)*

Funded by Singapore Initiative in Energy Technology (SINERGY) and the Innovation for Environmental Sustainability (IES) Fund; $50 million (SINERGY) and $20 million (IES Fund)

(b) R & D activities at universities

- Fuel Cell Strategic Research Program of the Nanyang Technological University (NTU)

  Formed in 2001, the Program has four main areas of focus: PEMFC, SOFC, Fuel cell systems and applications and related technologies (e.g. reforming). It has funded projects amounting to more than $3 million and has published more than 100 papers in international journals

- Activities at the National University of Singapore (NUS)

  NUS activities include: Electrochemistry; Composite polymer electrolyte systems; Nanotechnology and electrocatalysis; Hydrogen storage - carbon nanotubes, metal nitrides; and PEMFC power generation system

- Activities at A*STAR research institutes
  - Development of advanced polymer membrane (patented), and solid oxide materials
  - Materials modeling; engineering analysis
  - Fuel cell systems manufacturing technology and automation
  - Applied catalysis for fuel cells and hydrogen technologies
  - Exploit Technologies – supporting commercialisation of PEMFC (with Gashub)

(c) Private sector RD&D activities

- small start up developing fuel cell systems (PEMFC) using locally developed membrane
- testbedding projects
- alternative energy systems, fuel cell vehicle sub-systems

(d) Other hydrogen and fuel cell-related activities

- Power electronics / converters
- Hydrogen production and purification - Reforming
- Bio-hydrogen
- Industrial hydrogen production, PSA, gas separation

4 Ingredients and Pathways to a Renewable Hydrogen Economy in Asia

This section presents the highlights of the discussion on the ingredients and possible pathways to a renewable hydrogen economy in Asia. Speakers from various countries shared their insights and information on the availability and quality of renewable energy resources, including hydro, geothermal, biomass, solar and wind, and the existing policies and strategies for their development and utilization. Subsequently, representatives from different countries grouped into regional panels outlined possible pathways towards a renewable hydrogen economy drawing from their policies and experience in developing renewable energy resources.

4.1 Availability of Renewable Energy Resources

4.1.1 Geothermal Energy

In his introductory remarks, the session moderator, Dr. Guillermo Balce, Undersecretary, Philippines Department of Energy, noted that Asian countries utilizing geothermal energy for power generation, including the Philippines, Japan, Indonesia, China and Thailand, have geothermal resources which are considered excellent grade. These countries still contain considerable geothermal resource available for development.

4.1.1.1 Iceland

Resource Potential

As presented by Mr. Agust Valfells of the National Energy Authority of Iceland, the geothermal and hydro resources are largely untapped in Iceland. The geothermal potential for electricity production in Iceland is estimated at 20 TWh per annum but geothermal production in year 2002 was only 1.4 TWh. On the other hand, hydro potential for electricity production is around 30 TWh per annum but the production in 2002 was only 7 TWh.

Policy/Strategy for Development and Utilization

The government policy is to promote utilization of Iceland's clean and renewable geothermal and hydropower resources in harmony with the environment.

According to Mr. Valfells, the demand for hydrogen in Iceland, which is mainly for mobile applications, is roughly 100,000 tons of H_2 per year, or about 600 – 1000 MW installed power capacity. However, he said that geothermal vents and biomass would only provide a minimal source of hydrogen.

4.1.1.2 Japan

Resource Potential

According to Dr. Masakazu Takahashi of the Ministry of Economy, Trade and Industry (METI), Japan has developed 18 geothermal sites with total capacity of 535.3 MW.

Policy/Strategies for Development and Utilization

Dr. Takahashi cited the measures for promotion of geothermal energy in Japan as follows:

- Subsidy for Well Drilling and Development Study (max 50%)
- Interest-rate Subsidy (50% of interest)
- Tax Reduction
- Government's loan and investment programs

Dr. Takahashi concluded that geothermal energy is one of options toward renewable hydrogen economy in the future.

4.1.1.3 New Zealand

Resource Potential

According to Ian Brown of Hydrogen Technologies, Industrial Research Ltd, New Zealand has a total geothermal installed capacity of 435.3 MW and running capacity of 403.3 MW.

Policy/Strategy for Development and Utilization

The *Resource Management Act* (1991) is the core of legislation intended to promote the sustainable management of natural and physical resources in New Zealand. It has had a major impact on the pathways to develop and exploit energy reserves.

4.1.2 Hydropower

Ricky Aribiwowo of the ASEAN Center for Energy (ACE), Jakarta, Indonesia gave the introductory remarks on behalf of Dr. Weerawat Chantanakome, Executive Director of ACE who was unable to attend.

Mr. Aribiwowo said that all of the ASEAN member countries will encourage more hydropower development both on large and small scale, particularly micro hydro for rural electrification. There is a large untapped hydro potential in ASEAN with

4.1.2.1 Bhutan

Resource Potential

As presented by Mr. Karma Penjor Dorji, Planning and Coordination Division, Department of Energy, Ministry of Trade and Industry, Bhutan is endowed with abundant water resources with good quality. Hydropower potential is estimated at 30,000 MW. The technically feasible potential is 23,495 MW, of which the current installed capacity, is only 460 MW or roughly 2%. Hydropower capacity is expected to more than triple by 2006 to 1500 MW, but this will still be only % of the total potential.

Policy/Strategy for Development and Utilization

According to Mr. Karma Penjor Dorji, hydro power is the backbone of Bhutanese economy. Water has brought about the much needed economic development in Bhutan through careful planning of hydro power projects. Seventy five percent (75%) of the electricity generated is exported to India. Prior to harnessing hydropower, the Bhutanese economy was almost entirely dependent on foreign aid. The revenue from sale of hydro electricity provides 45% of national revenue and earnings are ploughed back into the social sector.

There has been no conflict between the hydropower sector and other users of water as the main rivers are rarely used for drinking or irrigation purposes. Hydropower projects in Bhutan are mainly run of the river schemes and have had minimal environmental impact.

4.1.2.2 Nepal

Dr. Jagan Nath Shrestha, of the Tribhuban University, Nepal, discussed the status of hydropower development in Nepal.

Hydropower Potential

- 6000 rivers in Nepal - total length 45,000 km; water discharge more than 200 billion m3; - elevation from 55 m to 8848 m
- Identified potential: 83,000 MW (1960s estimate?)
  - economical potential: 42,000 MW
  - present exploitation: < 550 MW
- After 2006/07 - a surplus energy even after meeting the domestic and the export demand.
- The surplus energy available is projected to be 13,886 GWh in year 2025/26

4.1.2.3 Sri Lanka

4.1.3 Biomass

Moderator and Introductory Remarks: Mr. Sreenivasa Setty, Foundation for Clean Energy and Environment, India – presentation missing

4.1.3.1 Indonesia

Resource Potential

According to Dr. Achiar Oemry of the Indonesian Institute of Sciences, Indonesia, biomass potential in Indonesia is estimated at almost 150 million tons per year or equivalent to about 470 GJ per year. The biggest source of biomass is the forestry sector, plantation and agriculture. Biomass accounts for about 40% of national primary energy consumption.

Power generation potential is estimated at 49,807 MWe but the installed Capacity is only 178 MWe, translating to only 0.36 % utilization. Indonesia has an ambitious target of increasing its biomass generation capacity to 18,000 MWe by 2020.

4.1.3.2 New Zealand

<u>Resource Potential</u>

Dr. Ian William Brown of Industrial Research Ltd., New Zealand gave the following account of biomass resources in New Zealand:

- Principal resource is forest waste from plantation forestry industry based on *Radiata Pine.* This resource is nationally dispersed, so it has the potential to meet distributed energy needs in most regional & rural communities
- 1.7M ha in plantations (6.5% NZ land area)
- *P. radiata* has approx. 25 year harvest cycle
- Current harvest is 18M m3; Harvest expected to be 30M m3 by 2010
- Potentially 2M tonnes usable waste annually at current production levels - this is equivalent to 20M GJ = to installed capacity of 600MW

<u>Projections</u>

- Considerable growth in forest biomass use (10-20PJ growth predicted by 2010 at current uptake and investment rates)
- Increase current total renewables from 29% to 35% of NZ's primary energy by 2010
- New technologies for alternative biomass streams:
  - Short rotation crops (primarily forestry eg. eucalypts)
  - Whey to ethanol from dairy industry

4.1.4 Wind and Solar

In his introductory remarks, the session moderator, Dr. David Renne of NREL, USA, noted three factors that distinguish renewable energy resources from other energy resources:

- Supply is generally never depleted
- Conversion to useable energy is controlled by resource availability, which varies from site to site and from time to time
- Supplies vary over time (storage often required: a good application for a hydrogen economy)

Dr. Renee also stressed the importance of having an accurate solar resource assessment to develops information on the availability of the solar resource at different locations and determines the solar energy available for specific technologies

Likewise, Dr. Renee cited the benefits of high-resolution wind maps, as follows:

- accelerate identification of promising areas for wind prospecting and project development
- Facilitate investment in large-scale wind energy projects
- Support informed decision-making by public and private sectors
- Accelerate the wind project deployment process

Dr Renne also talked about NREL's wind resource assessment projects in Asia particularly in the Philippines and Sri Lanka. He summarized NREL's approach as follows:

- Develop high-resolution resource data
- Integrate into GIS
- Incorporate options analysis tools
- Conduct in-country stakeholder engagement and capacity on RE policy, applications
- Develop feasibility studies
- Develop replicable projects

4.1.4.1 Philippines

Mr. Herman Guillen of the Energy Development Corporation of the Philippine National Oil Company

4.1.4.2 Malaysia

Dr. Kamaruzzaman Sopian, Universiti Kebangsaan Malaysia (UKM) talked about solar and wind resources and renewable hydrogen production in Malaysia.

<u>Summary</u>

- Solar radiation in the tropics – predominantly diffused in nature
- The use of concentrating solar collectors is not practical in most parts of the tropics
- Wind conditions are governed by the Monsoon seasons
- Wind Energy Conversion systems in coastal areas
- Potential Hydrogen production by PV and Wind
- Solar and Wind Mapping for Malaysia and Hydrogen Economy– (Joint collaboration with NREL)

Mr. Rupert Merer, Stuart Energy Systems, Canada talked about talked about the pathway forward in electrolytic hydrogen production.

<u>Large Scale Electrolytic H2 (> 1MW) Production – Pathway Forward</u>

- Pathway to cost equivalency with fossil fuels:
  - Electrolyser Development
    - Robust systems that handle highly variable inputs
    - Low cost electrolyser at US$300 /kW
    - Baseline efficiency 50 kWhr/kg (tied to capital cost)
    - Optimized to enable high over-potential
  - Renewable Power Development
    - Achievement of $.02-$.03 in excellent resource.
    - Can benefit from CO2 or other credits
  - Higher Priced Fossil Fuels
    - > $50 / barrel oil, > $12 /GJ NG
- When? Achievable by 2015
- Hydrogen technology may offer other benefits – air quality, efficiency, energy security etc.

4.2 Ingredients and Possible Pathways to a Renewable Hydrogen Economy

4.2.1 North Asia Panel: Japan and Korea

4.2.1.1 Japan

Dr. Masakazu Takahashi, Hydrogen and Fuel Cell Promotion Office, Agency for Natural Resources Energy, Ministry of Economy, Trade and Industry (METI) in Japan gave his insights on the possible pathway for promoting a renewable hydrogen economy and market expansion and market independence based on Japan's policy tools for NRE promotion.

<u>Japan's Policy Tools for NRE Promotion and Budgets</u>

- *Research and Development- Budget: FY2004: JP¥ 42.4 billion (US$385 million)*
  - Basic Reserch
  - Development for practical application

- *Demonstration program- Budget for FY2004: ~ JP¥26.5 billion (~US$241 million)*
  - Field tests
  - Demonstrative research

- *Subsidy for Promotion (full utilization of market mechanism) - Budget for FY2004: ~ JP¥94.6 billion (US$840 million)*

  - Creation of initial market for inducing market independency
  - Creation of environment suitable for introducing leading-edge new energy systems
  - Enlightenment and public information activities

  These measures are complemented by the following non-budgetary measures for NRE promotion:

  - Financial support (tax system, fiscal investment and loans)
  - The Green Purchase Law
  - New market development mechanism ～RPS (Renewable Portfolio Standard)

As a reference for the effectiveness of Japan's approach, Mr. Takahashi cited the growth of the residential PV power generation system, with the number of PV units having risen from only 24 at the start of the trial period in 1993 to 637 by 2002. Installation cost has correspondingly declined from million JP¥ 3.7/kW (~$33, 600/kW) in 1993 to JP¥ 70,000/kW ($ 636/kW) in 2002 and the power generation cost from 260/kWh ($2.4/kWh) in 1993 to 49/kWh ($0.44/kWh) in 2002. In 2003, Japan has by far the highest PV capacity among IEA/PVPS member countries with 859.6 MW followed by Germany and USA with 410 and 275.2 respectively.

Pathway for Market Expansion and Independence

- Development of new products - Technical development
- Period of market creation - Creation of initial demand
- Period of independence and expansion in the market - Synergistic effect of mass production and cost
- Period of market maturity

The period of market creation is the most important. For new energy equipment and facilities, the creation of initial demand (for boosting) at the time of introduction to the market will overcome the deterrent factors and enable the market to grow into a scale large enough to achieve independence, thus having a large advantage. Without the creation of initial demand, it is not possible to achieve market independence and it will be destined to disappear from the market due to competition with the existing products, thereby making past investment in technical development pointless.

Mr. Takhashi has earlier presented in the session on international renewable hydrogen energy experience a scenario practical application and diffusion of fuel cell vehicle and stationary fuel cell in Japan. and shown above in Sec. 4.3.1

4.2.1.2 Korea

Dr. Heesung Shin, Korea Institute of Energy Research, Korea also discussed the NRE policy and deployment experience in Korea as a possible approach for promoting a hydrogen economy.

Promotion of NRE Industry and Building a Supply Infrastructure: Mid- & Long-Term Strategies

Task 1: ***Securing Base Demand for Market Development***

- Mandatory installation of NRE facilities to the Newly Built Public Buildings
- Promotion of NRE Dissemination Business appropriate to the Local Conditions
- Strengthening of Dissemination Programs for Stable RNE Market
- Voluntary Programs: Green Pricing and Green Power Marketing Programs
- Green Certificates, Renewable Energy Credits (RECs)
- Introducing of Renewable Energy Portfolio Standards (RPS)
- Improving the existing Feed-In Tariff

Task 2: ***Incentives to enhance economics of NRE***

- Review of Premium Prices and Duration in Feed-In Tariff
- Feed-In Tariff may be applied to Thermal Sources
- Strengthened Incentives: Lowering Tariffs
- Reforming Governmental Financial Support

Task 3: ***Enabling Environment for NRE Industry Infrastructure***

- Demonstration Center for NRE
- Green Village for New and Renewable Energy
- Certification of NRE Facilities
- Designation and operation of NRE Assessment Center

Task 4: ***Reforming Legislation & Institutions***

- Strengthening Legislative Support for NRE Deployment
- Empowerment of NRE Development & Deployment Center
- Establishment of a Fund solely for NRE Promotion

4.2.2 South Asia Panel: Bhutan, India, Nepal, Pakistan, Sri Lanka

4.2.2.1 Bhutan

Mr. Karma Dorji, of the Department of Energy, Ministry of Trade and Industry said that the opportunity for hydrogen society development in Bhutan through renewable energy lies in the utilization of surplus energy from run-off river hydropower for hydrogen production.

4.2.2.2 India

In this session Mr. Chandan Roy of the National Thermal Power Corporation (NTPC) of India came up with two possible routes for the hydrogen economy based on his analysis of the demand for hydrogen and supply options. He argues that even if only 10 % of the total energy demand in India is replaced by hydrogen, the quantity of hydrogen required in 2020 would amount to 11.3 million MT. Such a large amount cannot be produced through renewable sources, or water electrolysis etc., or will be very costly especially in the medium term. Hence, he concludes that hydrogen generation from fossil fuels either through hydrocarbon reforming i.e., of petcoke or coal gasification may be the economic option. He argues further that large resources of coal and lower cost, makes coal ideal for large-scale hydrogen production in India.

Following are the two routes for pursuing the ultimate dream of a hydrogen-based power generation through fuel cells that Mr. Roy suggested:

<u>Hydrogen Roadmap - Dream 1</u>

This would deploy:

- IGCC
- H2 purification & carbon capture technologies
- Combust in advance class gas turbines
- MCFC and SOFC for power generation
- Also use H2 for synthetic petroleum

Hydrogen Roadmap - Dream 2

This would deploy:

- Thermo-chemical water splitting
- Use nuclear heat
- Use solar heat
- Create Hydrogen Grid
- Integrate with large fuel cells

4.2.2.3 Nepal

Dr. Jagan Nath Shrestha, of the Tribhuban University, Nepal, argues that Nepal cannot become rich by exporting its hydroelectricity alone and that the way ahead for Nepal is to use electricity to produce high value product like hydrogen fuel capable of replacing fossil fuel in transport. He outlined the future approach and needs for developing hydropower for hydrogen production.

Future Approach

- Analysis of Hydrogen fuel production based on the low growth, medium growth and revised high growth scenario of electricity surplus generation.
- Analysis of the substitution of the petroleum fuel in vehicles with the hydrogen fuel.
- Assessment of the environmental benefit.
- Analysis of the costs and benefits

Future Needs

- Technology Transfer from developed countries
- Manpower trained in hydrogen technology
- Establishment of small scale hydrogen plant
- Sharing of experiences in hydrogen energy production, research and development among the countries (South-South, North-South)

4.2.2.4 Pakistan

Dr. Muhammad Pervez of the Hydrocarbon Development Institute of Pakistan (HDIP) presented the proposed action plan for renewable hydrogen while Mr. Irfan Yousuf of the Alternative Energy Development Board talked about the options for hydrogen production.

Proposed Action Plan

- Policy Framework
- Financial incentives and budget allocation
- Public private partnership
- International collaboration
- Full use of international funding opportunities.

- Institutional Capacity building
- Human Resource Development
- Institutional arrangements, regulatory mechanisms and legislative frameworks for the development of renewable hydrogen.
- Separation of RD&D components and commercial applications.
- Technological dissemination and market development

Proposed Projects Open for International Cooperation

- Diesel CNG Substitution
- Hydrogen-CNG Mix in transport Sector

Available Options for of Hydrogen Production

- Electrolysis of water
- Steam reforming of Natural Gas
- Plasma Arc Process
- PV Electrolysis (Enormous Energy available)
- Wind Electrolysis (Enormous Wind Resource is Available)
- Steam Gasification of Biomass (Available)

4.2.2.5 Sri Lanka

Dr. Rahula Attalage of the University of Moratuwa, Sri Lanka presented a Sri Lankan perspective of the hydrogen economy particularly the focus areas, issues and pathway forward.

Focus Areas

- Public vehicles in Urban transport
  - ICE for Three wheelers, Buses (large no of vehicles and fleet size increases)
  - Off-grid power
  - ICE for off-grid power (20% households will remain unconnected to the grid for the next 30 years as per the CEB)

Issues/Constraints

- Lack of public awareness about safety of using H2
- Prevalence of a hostile environment until very recent
- Lack of Technological competence and Institutional capacity in producing, storing & transporting H2
- Insufficient information on the potential of private sector participation/joint ventures.

Pathway Forward

- Immediate/short term
  - Awareness of all stakeholders thro' Seminars/Workshops

- Pre-feasibility evaluation of ICE conversion of Three-wheelers & Buses
- Enhance existing course modules on Energy by introducing H2 economy
- Monitoring current trends of H2 economy for information
- Preparation of actions for demonstration project on Transport (H2 production & ICE conversion)
-

- Medium/Long-term
  - Implementation of demonstration project for transport using best practiced ICE
  - Monitoring performance & necessary action
  - Dissemination & sharing experience
  - Initiate action for off-grid option together with the experience in transport and the national wind power generation expansion plan

4.2.3 Southeast Asia Panel: Indonesia, Malaysia, Singapore, and Thailand

4.2.3.1 Indonesia

"ASEAN Hydrogen Millennium Initiative"

Dr. Jan Sopaheluwakan of the Indonesian Institute of Sciences, proposed an "ASEAN Hydrogen Millennium Initiative" taking into account certain factors specific to Indonesia and Southeast Asia as a whole. These are (a) the great diversity in the region in terms of economy and development, energy resources and culture and ethnicity; (b) national policies in Indonesia and ASEAN towards fossil fuel phase out; and (c) energy supply- demand picture.

The proposed ASEAN Hydrogen Millenium Initiative consist of defining a common ASEAN hydrogen vision and platform, supply side consolidation, demand side consolidation and a "Hydrogen Bank" as a regional buffering transactionary mechanism.

Supply side consolidation

1. Define the SEA hydrogen platform
   - The island path
   - The continental path
   - The rural path
   - The urban path
   - Combined path

2. Mutually reinforce research and development agenda
   - Pathways related to the hydrogen sources (biomass, seawater, fossil fuel, etc.)
   - Hydrogen purity and scale of production → FC types (stationary or portable FC)
   - Conversion modules

- Co-generation and hybridization
- Storage and delivery
- Application platforms → terrestrial vehicles, space and aero vehicles, household

3. Set up viable common milestones
4. Form a SEA Hydrogen Trust Funds (Can ASEAN Center for Energy take the lead?)

<u>Demand side consolidation</u>

1. Scale of economies and market assessment
   - ASEAN is a fast growing market (350 millions of population)
   - ASEAN energy self reliance ?
   - Fossil fuels are for export and added value product, hydrogen fuel takes the role as local energy supplier
2. Stakeholder awareness (public, industry, government, parliament)
3. Pilot projects
   - Regional interest
   - National and local interests

<u>Transactionary mechanism</u>

1. Form a regional "Hydrogen Bank"
   - Hydrogen as a common currency
   - Networked hydrogen storage facilities and market buffering institution
   - Member countries as the shareholders
   - Financial and incentives for investment in hydrogen economy
2. Legal and institutional bases
   - Trading protocols (incorporated in the ASEAN Free Trade Agreement)
   - Barriers to commercialization
   - Pricing policy

4.2.3.2 Malaysia

Professor Dr. Hamdani Saidi, of the Universiti Teknologi Malaysia, outlined a future scenario for the Hydrogen Economy in Malaysia in the context of the current status of the "hydrogen industry" and new government initiatives as presented earlier in Sec. 3.6.2 of this report.

Future Scenario for the Hydrogen Economy in Malaysia

- Development and deployment of:
  - Fuel Cell powered motorcycle

- Fuel Cell powered Bus air-conditioning
- Development and deployment
- 5 kW fuel cell system – development and deployment

- Possible demonstration projects
    - Fuel cell bus
    - hydrogen refueling station
    - Distributed power generations
    - Smart building
- Establishment of Research Centers
    - National Fuel Cell Centers
    - Institute for renewable energy
    - Solar Research Centre
- Intensification of R&D in:
    - Biofuels and hydrogen generation
    - Hydrogen storage
    - New materials for fuel cells
    - Direct hydrogen from solar
- Development of standards

4.2.3.3 Singapore

Mr. Hiang-Kwee Ho of the Nanyang Technological University, Singapore outlined the possible pathways to a hydrogen economy in line with the "apparent" policies and goals for Singapore's energy sector. He also argues that creating/joining a renewable hydrogen economy is probably in line with these goals, but Singapore is not rushing into it (yet), and they are hedging their bets. He also noted the issues and constraints.

Issues and Constraints

- No specific hydrogen energy policy (actually, Singapore does not even have an official "energy policy")
- No sufficiently aggressive incentives or measures to promote use of clean and sustainable energy technologies (e.g. in solar energy, or in "green" vehicles)
- Singapore has not ratified Kyoto Protocol
- Singapore will use whatever economical and competitive energy sources are available, even if they are not particularly "green"– e.g. of willingness to allow use of Orimulsion
- Singapore is relatively inactive in regional and international energy-related collaborations and initiatives (e.g. ASEAN, APEC)

Possible Pathways for a Hydrogen Economy

- Formulate and articulate clear, quantifiable energy policies and goals, including for renewable and hydrogen energy
- Pursue energy goals as aggressively as we have pursued our water supply goals (i.e., Singapore is investing billions of dollars in development and

deployment of recyling water and desalination capabilities taking into consideration non-economic social and environmental factors (i.e. internalise "externalities")

- Pursue aggressive capacity building, and research & development in advanced energy technologies (including renewable and hydrogen energy) by leveraging on Singapore's
  - technological strengths (and aspirations) in *refining, petrochemicals, chemicals, materials, electronics, info-comm technology, nanotechnology, bio-sciences,*
  - Our strength as a *reliable, responsive, responsible* testbedding and commercial hub
  - Regional and international efforts and initiatives

<u>Possible focus areas in renewable and hydrogen energy</u>

- Develop technologies for both conventional hydrocarbon energy processing and "bio-refineries" of the future exploiting vast biomass potential of the region and our experience with petroleum refining
- Design, develop and incorporate advanced/ intelligent IT in energy system/ network operation and management (enabling efficient, optimized, self-healing networks/ systems, complex networks with vast number of distributed resources, advanced diagnostics/ prognostics)
- Develop advanced power electronics as part of robust, flexible and sustainable energy systems
- Develop advanced materials and technologies (including bio and nano-materials and technologies) for renewable and hydrogen energy production, storage, distribution and utilisation (including fuel cells), but need to find niche focus areas

4.2.3.4 Thailand

Prof. Dr. Sombat Teekasap of FTI, Thailand outlined a fuel cell road map along with individual roadmaps for various renewable energy technologies in the context of the national energy policy and the strategies for promotion of alternative energy development and R&D Support.

<u>Fuel Cell Road Map</u>

2005:	R&D:Develop and Demonstrate Fuel Cells for Power Generation
2005-2009:	Information Data and Service System
2006 – 2009:	Develop and Demonstrate the Sustainable Production of Hydrogen
2007:	Fuel Cell Economy - With > 30% Local Content
2009:	With > 50% Local Content

Dr. Sombat concluded his presentation by citing the needs for implementing a hydrogen energy program, namely technical, environmental, social, economical, and political feasibility. He also argued that a successful program should be implemented at the RIGHT TIME, RIGHT PLACE, and RIGHT SITUATION. Nonetheless, he said that Thailand welcomes all initiatives toward sustainable and continuous improvement of energy supply to their Kingdom and that Thailand is ready to cooperate in any partnership program for regional and global development.

4.2.4 Philippines Panel: Representatives of Government, NGO, Industry, Academe

4.2.4.1 Government/Development Organization

Ms. Rosario Calderon of the Office of Energy and Environment, Philippine USAID Mission outlined the possible building blocks and strategies for pursuing a hydrogen economy in the context of the renewable energy policies cited by Energy Secretary Perez earlier.

Possible Building Blocks for a Hydrogen Economy

- Natural Gas Development Program
  - Malampaya gasfield and other areas
  - Infrastructure development Program
  - Deployment of CNG buses by 1Q 2005
- Renewable Energy Programs of the DOE/PNOC, the Private Sector and DOE's development partners
- Rural Electrification Programs
  - NEA and private sector programs
  - AMORE (Alliance for Mindanao Off-grid Renewable Energy)
- Environment Programs
  - Energy and Clean Air Project
  - Sustainable Energy Development Program
- Research Initiatives of the Academe and Research Institutions
- International Cooperation
  - Philippine leadership in APEC and ASEAN
  - Bilateral cooperation – w USAID, ADB, etc.

Possible Strategies

- Undertake Hydrogen Study/Develop a Hydrogen Roadmap
- Identify and pursue a pilot project
- Mobilize academic and research institutions
- Forge/strengthen strategic alliances on hydrogen w experienced countries and potential partners
- Conduct education and outreach programs

4.2.4.2 Non-governmental Organization (NGO)

Dr. Ibarra Cruz of the Foundation for the Use of Sustainable Energy and the University of the Philippines also gave his insights on a possible path or next steps to a hydrogen economy based on the experience in renewable energy development and an assessment of the fuel cell market he conducted earlier. He also cited the economic barriers to fuel cell deployment identified at the time.

Economic Barriers

- The capital cost of a commercially available 200-kW PAFC system is approximately US$4,000/kW,
- A life cycle cost comparison model was developed by the National Engineering Center at U.P. to analyze the cost difference of delivered energy between a 200-kW Toshiba-ONSI PAFC system and a comparable size diesel generator.
- The conclusions were that the fuel cell becomes competitive if (i) diesel fuel price increases 31% from the 1999 price level; or (ii) the fuel cell capital cost lowers to US$1,500/kW. Natural gas cost was assumed 2.226 Pesos/cubic meter (US$4/mBTU) at Tabangao, Batangas the Malampaya gas landfall.

Next Steps

- The 1999 Fuel Cell Seminar sponsored by USAID provided the first step that could have led towards the first fuel cell demonstration project in the Philippines.
- Interested host companies, namely PNOC and MERALCO, and the technology provider Toshiba Corporation in round table discussions.
- Funding requirement a barrier
- Follow-up discussions among interested parties must be resumed

4.2.4.3 Industry

Mr. Ramon Abaya of the Cagayan Electric Power and Light Company talked about his company's experience in developing a 950 kW Photovoltaic (PV) Project which was co-funded by the International Financing Corporation from the Global Environment Fund (GEF). This project could serve as a platform for a pilot project for hydrogen-based distributed generation using the excess or off-peak power from the facility to run an electrolyzer and produce hydrogen.

The end view of the project was to bring down the cost of installed PV system prices to $3,000/kW within 5 years should markets of several hundred MW per year can be pursued in conjunctive PV-Hydro use. The conjunctive operations of CEPALCO's Photovoltaic Solar Power Plant and Bubunawan Power Co. (BPC) Run-of-River Hydro is the first operational PV-Hydro tandem project in the world.

This project is to demonstrate the practical feasibility of conjunctive PV-Hydro operations that would convert variable outputs of a PV generation into a firm peak load energy without requiring additional investments in costly storage facilities.

4.2.4.4 Academe

Dr. Alvin Culaba of the Center for Engineering and Sustainable Development Research, De La Salle University also talked about the hydrogen-related undertakings of his organization and shared DLSU's experience in energy research.

Major research undertakings and outputs

- Hydrogen as fuel energy vector for transport vehicles
- Syngas and biofuels research
- Wind and solar energy systems

Energy Research: The DLSU Experience

- Research and Development (R&) can thrive effectively and efficiently in academic institutions
- Knowledge base of new and emerging technology such as hydrogen fuel research
- Availability of and access to local human resources and expertise and networking

Finally, Dr. Emman Anglo of the Manila Observatory (MO) and Ateneo de Manila University talked about the current activities of the MO on GHG mitigation and air quality improvement.

The Manila Observatory - Current Involvements

- Climate Change Information Center (Klima)
  - Promotion of climate change and GHG mitigation as a national and local agenda
- Urban Air Quality
  - Evaluation of benefits of transportation alternatives to public health
- Alternative Transportation
  - Hybrid gas/electric tricycle

Routes for Engagement

- Provide funds for R&D
- Integrate hydrogen in existing programs
  - GHG mitigation, urban air quality, alt. transport
- Take advantage of existing trends
  - High oil prices, existing and potential alternative energy sources already create a market
  - Hydrogen can overcome limitations of alternative energy in portability and energy-on-demand